T H E S I S

on

PRELIMINARY STUDIES ON THE MANUFACTURE OF COTTAGE CHEESE

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INTRODUCTION

The yearly production of cottage cheese in the United States during 1926 was reported as approximately 68,000,000 pounds. Assuming that about five pounds of milk are used to produce a pound of the finished cheese, it would mean that a total of 340,000,000 pounds of milk was used in the cottage cheese industry during the year. A considerable amount of cream is also used in the manufacture of the creamed product.

The 68,000,000 pounds of cheese reported includes cottage, pot and baker's cheese. The important difference between the varieties is that cottage cheese usually contains added cream when marketed. Creamed cottage cheese is often made from either pot or baker's cheese.

The state reports for the Pacific Coast States, Washington, Oregon and California, give the production of cottage cheese only. Pot and baker's cheese are not given, indicating that they have very little importance in this section of the United States.

In the three states mentioned above the cottage cheese industry has reached a place of considerable commercial importance. Several large commercial establishments make the production of cottage cheese their major enterprise.

The production of cottage cheese in three Pacific Coast states during the year 1926 was 15,080,433 pounds. In 1927 the production had increased to 17,933,000 pounds with an approximate value of slightly over two million dollars. This shows that nearly one fourth of the entire production of cottage cheese in the United States is produced in the coast states.

California is by far the leading cottage cheese producing state on the coast, 13,504,228 pounds being produced in 1927.

The production per year in the state of Oregon for the years 1925 to 1928, inclusive, were as follows:

1925	1,451,941 pounds
1926	1,427,789 pounds
1927	1,531,638 pounds
1928	2,026,286 pounds

The percentage increase in production for the year of 1928 over that of 1925 was 39.55 per cent.

STATEMENT OF THE PROBLEM

The magnitude of the cottage cheese industry is now sufficiently large to justify some experimental work on the manufacture of this product.

One of the main problems confronting the cottage cheese manufacturer is the production of a product of uniformly high quality. This applies especially to the small plant operator who is endeavoring to market his surplus skim milk in the form of cottage cheese.

The fact that there are factories devoted exclusively to the manufacture of cottage cheese makes the problem all the greater for the manufacturer who cannot give his entire time to the production of cottage cheese but has to make it one of several enterprises.

This work was undertaken with the idea of studying the different steps in making cottage cheese and to develop if possible a standard method of manufacture which should result in the production of a uniform finished product from day to day.

In this study all of the more common methods of manufacturing were tried. This made it possible to become acquainted with the different methods of manufacture and the limitations of each.

The primary object of the work was to determine if possible what factor or group of factors controlled the firmness of the curd. The uniformity in size of the curd particles is an essential feature in the manufacture of cottage cheese, therefore the greatest effort is to be spent in developing a procedure that will give a curd firm enough so that it may be cut and stirred without breaking up into small particles.

The studies were also conducted with the idea of developing a test that would give a measurement of the firmness of the curd before the cutting process.

HISTORICAL

Cottage cheese and soft curd cheeses of similar character have been used as food perhaps as long as milk has.

Thom & Fisk (21) state that cheeses made from sound skim-milk probably represent the most ancient form of cheese making. Their origin is lost in antiquity. This knowledge is based upon passages from early history.

Although there is no absolute proof of the statement, cottage cheese was probably made popular in this country by the early Dutch immigrants who settled in the state of New York. This assumption is based upon the fact that cottage cheese is often called Dutch cheese or Schmeer Kase. Van Slyke, Hall and Hart (1) in 1904 were among the first in this country to publish any work on cottage cheese. In their publication it is stated that cottage cheese is a popular home produced food and also that cheese makers manufacture considerable pot and baker's cheese. A small amount of cottage cheese is also produced. These investigators refer to the use of starter for curdling the milk and also mention the use of hydrochloric acid and acetic acid for curdling milk for cottage cheese. The use of either hydrochloric or acetic acid results in a cheese which is soft and quite sticky in texture.

The food value of cottage cheese and its ease of digestion merited attention as early as 1904-1905 when Snyder (2) at the University of Minnesota conducted a series of trials on the relative digestibility and nutritive value of cottage cheese, rice, peas and bacon. In these trials the food was given to men employed at hard farm labor. No ill effect was shown by the men fed on a ration containing 1.1 pounds of cottage cheese per day. The cheese proved to be very similar in digestibility to whole milk, and seemed to satisfy the appetites of the men during a three day period. The cheese was made by natural souring of skim milk.

For a period of years previous to the opening of the World War apparently very little was done in a commercial way toward the development of the cottage cheese industry. The production of cottage cheese did not seem to be of sufficient volume to warrant its listing as a separate product in the United States Census report until 1918. Before that time cottage cheese was included with other cheese.

During the pre-war period the practice of making cheese in the homes seemed to be gradually declining. This may have been due to the method of handling the milk supply, and also that people felt that "blue milk" or skim

milk had little food value as a human food.

Some cheese was being produced for city trade during this period. Michels (3) of North Carolina in 1909 gives a method for the manufacture of cottage cheese, which is satisfactory for supplying city trade. He produced curd by the use of lactic acid cultures in shot-gun cans and after draining and pressing the curd was ground. Then a small amount of sweet milk and cream was added. When the food economists of the United States saw the possibility that this country might become involved in the World War, they started an immediate campaign for the conservation of food products.

The United States Department of Agriculture with the cooperation of Herbert Hoover launched a large campaign for the conservation of food products and especially meats, as this was needed for the armies. In their campaign increasing the consumption of dairy products and by-products was the chief motive. Special emphasis was put on increasing the consumption of dairy products in the south and also on increasing consumption of milk in the cities.

Every effort was spent in increasing the manufacture of cottage cheese on the farms and in the homes. Circulars and press notices were distributed as a means of

educating people to the food value of milk and cottage cheese.

Personal instruction was given to creamery operators and home economics teachers. Six experts devoted their entire time to the farm manufacture of cottage cheese.

The work was first started in the mountainous regions in the south and in September, 1914 the first cheese factory was established in North Carolina. By the year 1917 there were thirty-four factories in that State.

At the same time nine men were employed in the western states during the summer months. Their task was to promote the utilization of creamery products in order to eliminate waste of food material. The work was conducted in eight states and further work was planned.

As a result of this stimulation many creamery operators saw the possibility of developing a market for a surplus product such as skim milk. The public had been educated to the value of cottage cheese. All that was needed was further development of the industry on a large enough scale so that cottage cheese could be produced in sufficient quantities to enable them to furnish a quality product at all times.

Many plant operators saw the possibilities and kept

the product before the public. Advertising campaigns and a system of carefully planned marketing methods have greatly helped to place the cottage cheese industry in the important position it holds today.

One of the most noticeable things about the cottage cheese produced on the Pacific Coast is the uniformity of quality not only in flavor, but also in the size and texture of the curd particles. Constant effort is made to produce the curd in small cubes about one-fourth to three-eights inches on a side. The more uniform the manufacturer keeps the size of curd particles and the fewer small pieces of curd which are present, the better the product will appear when it is marketed and is therefore a better selling product.

The second main difference in this cheese and the cheese usually produced in other parts of the United States is the amount of milk and cream that is incorporated into the curd after it has been cooked and pressed. The cottage cheese producers in the Coast sections try to use as nearly as possible equal amounts of standardized cream and curd for each pound of cheese produced and yet keep the curd from becoming mushy and leaky. The finished curd when placed on a flat dish should not show signs

of leakiness of milk, cream, or whey.

Reicharts and Davis (10) at the Nebraska Station recommend the addition of cream to the curd at the rate of one pound of 12-15% cream to three pounds of curd.

Michels (3) obtained a yield of about one pound of cheese from every 7.1 pounds of milk. He added 3 to 4 pounds of milk to every 11 or 12 pounds of curd. The curd was ground rather coarsely and was dry and sticky in texture.

Ellenberger (4) experimented with the storage of cottage cheese at the Vermont station. The cheese was stored at a temperature of 14 to 16 degrees Fahrenheit for a period of approximately five months. He states that the curd was dry in texture at the time of storage. He recommends the mixing of a small amount of fresh curd to improve the flavor of storage cheese at the time it is marketed.

Morely (20) tried storing cottage cheese in hermetically sealed cans. The air in the can was displaced by forcing in carbon dioxide. He stated that this method is very effective in checking mold growth.

MATERIALS AND METHODS

The experimental work of this problem was conducted in the College Creamery. No equipment was used at any time that would not be available to the ordinary creamery plant operator.

The equipment used in the manufacture of the cottage cheese consisted of two small cheese vats 24 by 36 inches.

The batches of cheese were made in three series. Series one was made during the months of July and August, 1928. Series two and three were made in April, 1929. To the first series of batches, wire curd knives, which cut cubes of three-eights inch dimensions were used. In the later experiments knives with a cut of three-fourths of one inch were used.

A small curd press was made and used in series two and three. It consisted of a small wooden frame with a wooden slat bottom. It was equipped with a wooden follower fitting inside the frame. Two fifty pound weights were used for the pressing. This gave a 100 pound continuous pressure.

The curd was stirred with a small flat paddle.

In an effort to find some means of expressing the

condition or firmness of the curd in definite terms, a small curd knife was secured. This was a star shaped knife with ten blades. The idea of the knife was taken from the work of R. L. Hill (22) who used the knife used to test the physical hardness of a curd formed from milk that was to be used for infant feeding. One knife was secured from Dr. Hill and with this as a pattern three more were made. The knife had a three-eighth inch blade with center tapered to fit over a one-eighth inch stem. The blades were made from one-tenth inch tinned sheet copper and were three-sixteenths of an inch wide. The knives made here were not sharpened. The blades made a 36 degree angle and were soldered into the base. The diameter of the knife was two inches. Six hundred cc. beackers were used as containers for the curd in testing.

To find the tension of the curd a system of two small pulleys were fastened to a wooden frame. This was supported by a clamp from two ring stands. A small hard twist cord was threaded through the pulleys and two small wire hooks were fastened on either end. One hook was placed in the eye of the knife and the other was attached to a weight container.

Various denominations of gram weights were added

until the knife pulled up through the curd. The rate of speed was kept as nearly the same as possible in every instance. The rate was approximately one inch per second.

In making the acidity tests either 9 or 18 grams of milk curd were titrated against tenth normal sodium hydroxide using phenolphthalein as an indicator.

The milk used in making the cottage cheese was secured in most cases from the college herd. It was pasteurized at 142-145 deg. Fah. for 30 minutes, cooled to 90 deg. Fah. and then separated. The separated milk was then placed in the cooler at 40 deg. Fah. and held until that evening or in some instances until the next evening. The separation was done from ten to eleven o'clock in the morning.

The starter used for series number one was made from a culture obtained from the Erickson Starter Company at St. Paul, Minnesota. A fresh starter was made every two days.

A culture containing the microorganisms Streptococcus lactis and Streptococcus citrovorous was obtained from the Dairy Department, Iowa State College, Ames, for the starter used for series two and three. This starter was reinoculated every day and was very uniform in flavor, body and texture.

CHEMISTRY OF COAGULATION

Van Slyke, Hall and Hart (3) found that when cottage cheese is made by souring the milk by the formation of lactic acid, which is formed by the bacterial action on the milk sugar, the following points are of importance. First there is a decrease in the lactose content. As fast as lactic acid is formed it reacts with the casein salts of the milk, mono-calcium caseinate, to give free uncombined casein and calcium lactate. The acid content of milk is often stated in terms of lactic acid when in reality the acid is in combined form with the calcium salts of the milk. When milk first shows signs of coagulating about 13 or 14 per cent of the casein is in the form of mono-calcium caseinate and 86 or 87 per cent in the form of uncombined casein. With further increase in acid the mono-calcium caseinate loses its calcium and becomes free casein. The proteins found in cottage cheese made by souring the milk with acids were casein and mono-calcium caseinate. When rennet and acid are used para-casein and mono-calcium paracaseinate are formed.

In the presence of acid such as lactic acid and hydrochloric acid, a molecule of calcium caseinate containing four equivalents of base is split by rennet into two

molecules of paracaseinate, each containing two equivalents of base. Such a paracaseinate is soluble in pure water but is insoluble in the presence of more than a trace of a soluble calcium salt. If the original molecule has only two equivalents of base it is split into two molecules of paracaseinate, each containing one equivalent of base. Such a paracaseinate is insoluble in pure water. The rennin enzyme is not a coagulating ferment. The coagulation is a secondary effect, being the result of a change in solubilities.

THE SETTING OR RIPENING OF THE MILK

The milk was always set in the evening where starter alone was used to coagulate the milk. This curd was usually cut between eight and nine o'clock the next morning. This gave a setting period of between 15 and 20 hours, which is sufficient time for the milk to become completely coagulated.

In series one the vat was in the main room of the creamery and control of the temperature was impossible. This was found to be especially true in the winter months when several attempts were made but low temperatures resulted in a curd which was soft and shattered badly at the time of cutting.

Series two and three were made in a room in which the temperature could be maintained fairly constant.

The milk was heated to the temperature desired by running hot water through the jacket of the vats. Then as the temperature of setting was approached the warming water was tempered to the setting temperature.

The milk was allowed to come to the desired temperature and the jacket was left full of water.

The amount of starter added to the milk was from one to 18 per cent. Just before the milk reached setting

temperature the starter was added through a fine mesh strainer to break up the lumps.

Coloring was formerly added at this time but during the summer of 1928 notice was sent out that a ruling had been put into effect by the United States Pure Food Commission prohibiting the use of cheese color in cottage cheese. After that time no coloring was added.

After the starter was thoroughly stirred into the milk the vats were covered with a canvas and left until the next morning.

Since curdling in case of cottage cheese made without the use of rennet is due to the action of the acid, in several preliminary tests the acid was added to fresh skim milk without waiting for the bacteria to form the acid. The experiment was tried using lactic acid, the natural acid found in milk, and also chemically pure acetic acid, and hydrochloric acid. Previous tests showed that the action of added acid has a decided curdling effect even in small amounts. Therefore smaller amounts of the acid were used and this was diluted in ten times the volume of water. Milk at a temperature of 90 deg. Fah. was placed in small containers and enough acid to make two tenths of one per cent acid was added. In this trial acetic, lactic, and hydrochloric acids were used.

In a second trial in the experimental vats with the temperature of the milk at 40 deg. Fah. six-tenths of one per cent of acetic and two-tenths of one per cent hydrochloric acid were added. The pure acid was diluted to ten times its volume with water before it was added to the milk.

CUTTING THE CURD

Cutting the curd is one of the most important operations from the standpoint of a uniform product. Careless or rough handling of the knives causes an excessive amount of shattering and very small curd particles.

The knife making the horizontal cuts was used first and was lifted out each time. Less shattering occurred this way than when the knife was swung around in the curd. The knife making the vertical cuts was also lifted out after each cut. In the small vats even with great care in cutting there was a heavy loss from shattering. This is much more noticeable when a small mesh knife is used.

COOKING THE CURD

The cooking of the curd may be done in a number of ways, such as using direct steam in the jacket, by the use of steam to heat the water in the jacket, or by running warm water through the jacket.

In preliminary tests more success was had with the use of hot water. In all of the batches of cheese in the first series as soon as the curd was cut water at 120 deg. Fah. was run in on top of the curd to a depth of about two inches. To keep the water from mixing with the curd a tin plate was held just at the surface of the curd and the water flowed over the edges. In this manner shattering of the curd was avoided. The addition of two inches of water on the surface of the curd resulted in a temperature of the water of about 120 deg. Fah.

The water was then turned into the water jacket at 120 deg. Fah. and left running at this temperature until the curd could be stirred.

In stirring the curd, that next to the edge of the vat was handled first. Then as the temperature became higher the entire vat way stirred.

Then the temperature of the water was gradually increased until the curd reached the temperature where it was firm enough to wash and drain.

In series two, which was also starter coagulated, no water was run on to the curd. The curd was cut as in series one and then water circulated through the jacket at 100 deg. Fah. from 20 to 40 minutes. Although the temperature of the curd had not increased over three degrees considerable whey had been expelled. The temperature was increased to 110 deg. Fah. and the stirring was started. The temperature was then gradually raised until the curd became firm. The final temperature ranged between 118 and 130 deg. Fah.

In series three, with the curd that contained rennet as well as starter a similar procedure was followed. Preliminary tests indicated that rennet curd would mat considerably if the water in the jacket was above 105 deg. Fah. Although the curd could be stirred almost immediately after cutting without serious loss by shattering, it was better to heat the curd at 90 deg. Fah. for ten minutes before stirring commenced. The final temperature was usually lower than that of the curd without rennet.

WASHING THE CURD

The curd was washed by two different methods. The first method was to wash first with water at 100 deg. Fah., then, after draining, water at 70 deg. Fah. was added and drained, and lastly it was washed with as cold water as possible which was usually at a temperature of 50 and 54 deg. Fah.

The second method was to add water at 50 deg. Fah. in the vat as soon as the whey had started to drain. The vat gate was left open until the free whey was nearly all washed out. Then the gate was closed and the curd was covered with cold water for two or three minutes. The water was drained off and the curd put in the press for fifteen minutes.

It was then weighted and processed or stored away.

CREAMING THE CURD

The curd may be creamed by several methods. The cream may be standardized to such a per cent that when added to the curd the fat content of the cheese will be from five to seven per cent butterfat. The aim is to get one pound of cream to one pound of curd. If this can be accomplished the cream should contain fourteen per cent butterfat. The cream is best incorporated by letting curd stand from one to three hours and then mixing by hand stirring or by a machine similar to a bread dough mixer.

A second method of mixing which is satisfactory and results in a rich appearing product is to weigh out the amount of curd to be creamed. Then add an excess weight of skim milk and let the curd soak in the skim milk from one to two hours. The excess milk is drained off and from the amount drained off the total weight of the soaked curd may be calculated. Enough cream containing 30 to 40 per cent butterfat to make the finished cheese test about 7 per cent butterfat is added and thoroughly mixed with the curd. This produces a cheese with a much richer appearance than does the method mentioned above. If the cream is homogenized at about 1000 pounds

pounds pressure or if a small amount of liquified gelatin is stirred into the cream before it is added to the cheese it will be more viscous and give the cheese a more firm appearance.

While there is criticism on the part of some manufacturers as to the use of gelatin in the cream, as yet there are no laws prohibiting its use and it is of sufficient importance to receive comment.

The gelatin is added at the rate of about one-half ounce to one gallon of cream. It is first soaked in a small amount of cold water, the solution is then heated to 160 deg. Fah., and the cream is added very slowly to this with vigorous stirring. If the cream is added too quickly the gelatin will solidify and its effect will be lost. Once the gelatin is thoroughly incorporated with the cream there is no danger of solidification.

STORAGE OF COTTAGE CHEESE

No attempt was made to conduct a storage trial on the cheese. In storing cottage cheese the dry curd is always stored. Curd was found to remain in good condition for more than a week at a temperature of 35 to 40 deg. Fah. in the College Creamery.

RESULTS OBTAINED

The procedure followed in each series of run was kept as near the same from day to day as conditions permitted.

The age of the milk and the method of separation and pasteurization were quite uniform throughout the period.

At various times some parts of the procedure which were thought to exert considerable influence on the final quality of the product were varied to some extent.

In Table I the data obtained from a series of fifteen batches of cottage cheese made with the use of starter for coagulation of the milk is shown.

The amount of starter used varied from one to twelve per cent of the weight of the milk. This variation was made to check if possible the relationship of the original amount of starter and the total acidity formed and also whether a heavy inoculation of starter would influence the quality of the curd.

TABLE I

Data showing the conditions of manufacture of cottage cheese in series number one. Lactic acid cultures only were used to coagulate the milk.

Batch Number	Amount of Milk Pounds	Acidity of Milk per cent	Starter per cent	Temperature of Coagulation deg. Fah.	Length of Coagulation Period Hours
1	170	.15	2	86	16
2	140	.14	2	84	18
3	112	.15	2	78	17
4	130	.14	2	80	16
5	97	.16	2	69	17
6	85	.18	2	76	17
7	87	.17	1	74	
8	135	.15	2	76	
9	79	.16	2	84	17
10	135	.14	1.5	84	16
11	138	.14	2	84	17
12	140	.18	8	84	22
13	140	.16	1.2	80	22
14	180	.17	9.8	78	21
15	168	.14	12	73	22

TABLE I
(CONTINUED)

Temperature at Cutting deg.Fah.	Acidity at time of Cutting per cent	Temperature started to stir deg. Fah.	Time to heat Hours	Final Temperature Deg.Fah.	Yield of Curd per cent
78	.82	96	2	140	14.4
72	.88	100	2	142	14.36
70	.87	86	1½	128	16.07
70.5	.85	96	1½	126	16.4
76		90	1	126	16.49
72	.92	100	1¾	120	17.05
*					
*					
70	.95	100	1	126	17.72
70	.90	100	1	128	
72	.83	90	1	126	15.21
72	.90	90	1	126	17.18
74	1.00	90	1¼	128	17.21
68	.92	110	1	140	
76	.83	92	1½	122	16.32

* The milk failed to coagulate because of the use of poor quality starter and the cooking process was not finished.

With the setting temperatures between 70 and 80 deg. Fah. and the temperature at the time of cutting between 68 and 76 deg. Fah. the batches with over 8 per cent of starter had only a slightly higher average of acidity than those batches which contained one to two and one-half per cent starter. There was not enough difference in the final acidity to warrant any conclusion when it is taken into consideration that the setting period for the batches with the higher per cent starter was about 22 hours in length as compared with 16 to 18 hours of those to which a small percentage had been added.

The reason for this longer period is accounted for by the fact that the milk was set late in the morning in order to find if the cheese could be cooked that evening. In every case it was found that a period of 6 to 9 hours did not give sufficient coagulation with the temperature and amount of starter used.

In batches number seven and eight in which one and two per cent was used not sufficient acidity was developed to give a satisfactory curd in a 16 hour period.

The four times that a high percentage of starter was used resulted in a curd which was softer and more easily shattered during the cutting process.

The results of the trials shown in table one seemed

to indicate that as a general rule the curd at the time of cutting will be similar in body to starter. In batch number one especially, the curd appeared quite firm until cutting and then it shattered badly during cutting and the fore part of the cooking process.

In batches number seven and eight the effect of poor quality starter was shown quite noticeably. In batch number seven the starter used was new inoculation and was decidedly off flavor and lacked smoothness. With a one per cent inoculation it took two days to form enough acidity to coagulate the milk and the curd formed was very soft and had a bitter flavor.

Batch number eight was made with a continuation of the same starter used in batch number seven. The original starter used in batch seven had an acidity of .75 per cent but was rather flat in flavor. The milk was set at 76 deg. Fah. but the temperature dropped to 66 deg. Fah. during the night. At the end of 15 hours the acidity was only .37 per cent. The temperature was raised to 82 deg. Fah. and at the end of 21 hours the acidity was only .40 per cent. At the end of 48 hours the acidity was only .66 per cent and then only traces of curd were near the bottom of the vat.

The starter organisms evidently lacked enough vitality to predominate. The next batches of cheese were not affected by slow coagulation although several inoculations were necessary before much improvement of the starter was obtained.

The addition of water at 120 deg. Fah. on the surface of the curd had a decided effect upon the rate of cooking and also aided in the warming of the curd to a temperature where it could be stirred. From one to five minutes contact of the curd particles with water at this temperature firmed them sufficiently to permit handling without danger of shattering.

It was found that usually the temperature of the curd should be raised about 10 deg. Fah. before it could be stirred in a satisfactory manner without injury. It was impossible to prevent some shattering even then. The length of the cooking period and the final temperature to which the curd was heated varied considerably with the different batches and it was impossible to follow a definite schedule from day to day.

In series one and two the curd was cut into cubes of 3/8 inch dimension. It was found that the final product resulted in too small and usually too firm a curd. After the curd was washed, considerable difficulty was

found in getting the cream incorporated with the curd. At times it took from 8 to 12 hours before the cheese became softened and showed a smooth creamy appearance. This was undoubtedly due to the amount of exposed surface compared to the volume of the particle.

In washing the curd made in series one, it was washed three times with the temperature of the water at 100, 70, and 54 deg. Fah. respectively. If the last washing was ommitted it was found that the curd later leaked considerable whey. In series two and three the curd was washed with water at 54 deg. Fah. only. In this method the valve gates on the vats were left open until most of the free whey had been washed out, then the gates were closed and the curd covered with water. The curd was stirred and left for approximately five minutes. By this time it was thoroughly chilled. The wash water was then drained off and the curd pressed for fifteen to twenty minutes. Pressing for a longer period did not seem to materially decrease the moisture content of the cheese. This would be of importance where large amounts of curd had to be pressed.

Table II shows the data obtained from the second series of batches. All factors were quite closely controlled and the only change in the method from series number

one was that no water was added to the curd at the time cooking began. In series number two water at 100 deg. Fah. was circulated through the jacket for 40 minutes before an attempt was made to stir the curd.

TABLE II

Data showing the conditions of cottage cheese in Series Number Two. Lactic acid cultures only, were used to coagulate the milk.

Batch Number		Milk Used Pounds	Acidity of Milk Per Cent	Starter Used Per Cent	Temperature of Coagulation Deg. Fah.	Length of Setting Period Hours
I	A	125	.25	2	70	16½
	B	125	.25	2	70	16½
II	A	125	.21	2	70	15¼
	B	125	.21	2	70	15¼
III	A	215	.20	2	70	15¾
	B	No duplicate - commercial batch				

TABLE II
(CONTINUED)

Temperature at time of Cutting Deg. Fah.	Acidity at time of Cutting Per Cent	Temperature started to stir Deg. Fah.	Total time of Heating Hours	Final Temperature Hours	Yield of Curd Per Cent
67	1.00	75	2	125	11.8
68	1.00	75	2	125	12.2
64	.89	68	2	118	11.6
68	.99	72	2	130	12.6
70	.95	76	2	120	12.56
No duplicate - commercial batch					

Preliminary attempts showed that if the temperature was raised much over 100 deg. Fah. the curd near the bottom, sides, and edges of the vat would mat considerably. The same difficulty of excessive shattering of the curd at the time of cutting was again experienced in this series. The importance of temperature control during cold weather was clearly shown in preliminary tests as well as in the actual experiment. The temperatures of the curd in vat "A" in batch Number Two had dropped to 64 deg. Fah. during the setting period while the curd in vat "B" was 68 deg. Fah. The curd in vat "A" shattered considerably more than that in vat "B" and resulted in a decreased yield. Vat "B" of this batch was considered the best cheese of the series.

Preliminary tests with small amounts of rennet indicated that the shattering of curd could be eliminated to a considerable extent.

The curd made with the use of rennet showed much more firmness and the cooking temperatures had to be reduced considerably.

The preliminary work also indicated that only a small amount of rennet was needed and that the acidity should be lower than when the milk was coagulated by starter cultures alone.

Table III shows the data obtained from batches of cheese made with varying amounts of rennet.

TABLE III

Data showing condition of manufacture of cottage cheese in Series Number Three. Various amounts of rennet used with lactic acid cultures to coagulate milk.

Batch Number		Milk Used Pounds	Acidity of Milk Per Cent	Acidity of Starter Per Cent	Rennet per 1000 Pounds of Milk cc.	Temperature at Time of Setting Deg.Fah.	Length of Setting Period Hours
I	A	125	.40	.2	1.5	72	4
	B	125	.25	.2	1.5	71	4
II	A	165	.20	.1	1.0	70	6
	B	165	.20	.1	1.0	70	6
III	A	125	.20	.2	.5	72	$9\frac{3}{4}$
	B	125	.20	.2	.5	72	$9\frac{3}{4}$
IV	A	145	.18	.1	.1	70	$12\frac{1}{2}$
	B	145	.18	.1	.1	70	13

TABLE III
(CONTINUED)

Temperature at time of Cutting Deg. Fah.	Acidity at time of Cutting Per Cent	Temperature Started to Stir Deg. Fah.	Total Time of Heating Hours	Final Tempera- ture Deg.Fah.	Yield of Curd Per Cent
71	.63	Broke up			
71	.52	75	3/4	94	7.2
72	.28	72	1¼	100	8.18
74	.34	74	1	90	8.48
76	.75	76			
76	.75	76			
69.5	.80	74	3	130	11.03
69.0	.70	74	2¼	120	16.56

In batch number one the amount of rennet used was 15 cc. per 1000 pounds of milk. The acidity of the curd in Vat "A" and "B" was .63 and .52 per cent respectively. The curd was very firm and was cut into cubes of three-quarter inch dimensions. Considerable difficulty was experienced in keeping the curd particles from matting together. In vat "A" the curd crumbled when the cooking was started. The particles matted together even after they had been washed. A film formed on the surface preventing proper expulsion of whey from the cubes. This curd was very tough and rubbery. The curd of batches two and three were in similar condition to that of number one, with the exception that there was less tendency to mat. Batch three was only partly cooked when the steam supply was cut off and the work had to be discontinued.

In batch number four one cubic centimeter of rennet per one thousand pounds of milk was used. The acidity of vat "A" was .80 per cent and that of vat "B" only .70 per cent. Vat "B" cooked very easily and stirring was started almost immediately after cutting. As shown by the final temperature of 120 deg. Fah. the rennet did not materially affect the cooking temperature. The curd had a very good texture and still contained sufficient acid to give a pleasing flavor after the curd had been washed.

The use of knives giving cubes with a dimension of three-quarters of an inch cannot be recommended because curd particles are too large to suit the trade. Also there was a tendency for the cubes to split on the sides to permit expulsion of the whey. A knife with a one-half or a five-eighths inch mesh should be much more desirable both from the standpoint of cooking and from the size of the cooked curd particles.

Several preliminary tests were made with a sharpened star shaped curd knife to compare firmness of different starter curds, and also with curd formed with the use of rennet.

The pull or tension that was required to pull the knife from the curd was only approximate because a small amount of pull would slowly pull the knife out in time. The tensions listed in Tables Number Four, Five, Six, and Seven represents the amount of weight required to lift the knife from the curd at a fairly quick rate of speed. In the first test a beaker was used as a container for the curd and kept in an incubator that maintained a temperature between 72 and 76 deg. Fah. The knife used had sharpened blades.

Table IV gives the results found with starter formed curds at different temperatures and acidities. The curd

with the highest acidity gave the greatest tension. Number five shows a greater pull but is not comparable due to a lump of curd clinging to the base of the knife. All of the samples with the exception of sample one represent actual conditions of the vats. The beakers were suspended in the vats in such a way that the milk could not run into the beaker. The milk in the beaker was dipped immediately after the milk had been set and put into position.

At the time of testing the milk containers were taken from the vat and placed in the tension testing apparatus. The tension was read and recorded. The first sample was coagulated in an incubator that maintained a temperature between 72 and 76 deg. Fah.

TABLE IV

The effect of coagulation temperature and acidity on the firmness of curds formed with starter. Test made with sharpened curd knife.

Sample Number	Temperature during Coagulation Deg. Fah.	Temperature at time of Testing Deg. Fah.	Acidity of Curd Per Cent	Gross Curd Tension Grams	Net Curd Tension Grams
1	76	76	.75	40	22
2	74	69	.975	40	22
3	70	67	1.00	50	32
4	70	64	.89	40	22
5	72	71	.62	60	42
6	70	72	.30	*	*
7	72	76	.78	30	12
8	70	69.5	.83	30	12

* Tension unmeasurable.

Table V shows influence of rennet added at the rate of 15 cc. per thousand pounds of milk. The milk was all kept in the incubator mentioned above. The table shows that with a constant temperature and rate of rennet the amount of acid has a direct effect on the firmness of the curd. The extreme tension varied from 32 grams net, with a .20 per cent acidity to 142 grams with a .89 per cent acidity.

TABLE V

The influence of the addition of rennet on the firmness of curds of different acidities as tested by a sharpened curd knife. Amount of Rennet used - 15 cc. per 1000 pounds of milk.

Sample Number	Temperature During Coagulation Deg. Fah.	Temperature at Time of Testing Deg. Fah.	Acidity of Curd Per Cent	Gross Curd Tension Grams	Net Curd Tension Grams
1	75	76	.89	160	142
2	76	76	.20	50	32
3	76	76	.64	150	132
4	76	76	.35	120	102

Table VI shows the various curd tensions as measured by an unsharpened knife. The acidities were rather low as they were used as a check on the rennet curd and the differences in tension were not so noticeable. The coagulations of the milk were accomplished in the same manner as those given in Table Number Four, that is the beakers were placed in the milk in the vats and the test made just prior to cutting the curd.

TABLE VI

The effect of variation in acidity and temperature on acid formed curd, measured by an unsharpened curd knife.

Sample Number	Temperature at Time of Coagulation Deg. Fah.	Temperature at Time of Testing Deg. Fah.	Acidity at Time of Testing Per Cent	Gross Curd Tension Grams	Net Curd Tension Grams
1	76	76	.47	30	9
2	70	74	.35	*	*
3	72	76	.80	40	19
4	70	69	.76	30	9

* Tension unmeasurable.

Table VII shows the effect of varying acidities and different amounts of rennet on the firmness of the curds as expressed by the curd tension. The curd containers were placed in the vats as in previous tests and the tests made at the time of cutting.

The results shown in Table Number Seven indicate that in all probability when acid and rennet are combined and used to coagulate milk, the variations in acidity have a greater effect on the firmness of the curd than small variations in rennet.

As shown by sample number eight one cc. of rennet per thousand pounds of milk with an acidity of .70 per cent gave a tension of 50 grams. Sample number four containing 10 cc. of rennet per thousand pounds of milk with an acidity of .34 per cent also gave a tension of 50 grams while sample number four contained approximately one-half as much acid with the same tension as that found in sample number eight.

The forming of curd with added acid apparently has no practical application in the manufacture of cottage cheese. Using acetic, lactic, and hydrochloric acid in sufficient quantities to give .20 per cent acidity did not give complete coagulation except on the surface.

TABLE VII

The effect of variation in setting temperature, acidity and amount of rennet used on the firmness of the resulting curd as measured by an unsharpened curd knife.

Sample Number	Temperature During Coagulation Deg. Fah.	Temperature at Time of Testing Deg. Fah.	Acidity Calculated as Lactic Acid at Time of Testing Per Cent	Rennet Per 1000 Pounds of Milk cc.	Gross Curd Tension Grams	Net Curd Tension Grams
1	72	71	.625	15	100	80
2	71	71	.52	15	90	70
3	70	72	.28	10	50	30
4	70	72	.34	10	70	50
5	72	76	.75	5	130*	110*
6	72	76	.75	5	200*	180*
7	70	69.5	.80	1	70	50
8	70	69	.70	1	70	50

* Lump was formed on base of knife which made tension reading too large.

Only milk which came in contact with the acid was coagulated. When acetic acid was used in quantities resulting in .60 per cent acid in the milk, a hard curd was formed. The curd was tough and stringy and could not be cut. The addition of acid gave too rapid a coagulation to form a smooth curd.

Pressing the curd at a low pressure for fifteen minutes gave a product that was less liable to be leaky in body and also expelled the whey which kept the curd from souring so quickly.

The best results were obtained in creaming where the curd was first soaked in an excess of skim milk and after draining off the excess milk, cream of a sufficiently high butter fat content to give the desired per cent of fat to the finished product was incorporated.

DISCUSSION OF RESULTS

Experimental work in the manufacture of cottage cheese when starter was used as the coagulating material showed unsatisfactory results in that a uniform product could not be produced.

Data taken from series one and series two showed that when the milk was of good quality and had been pasteurized previous to the coagulation period the resulting curd at the time of cutting resembled in body and texture the starter used. Coagulation of the curd between 70 deg. Fah. and 80 deg. Fah. produced a smoother and more desirable curd than did coagulation either above or below this temperature range. In every case where the entire coagulation period was at temperatures lower than 70 deg. Fah. a soft bodied curd was obtained. There was an excessive amount of shattering at the time of cutting and also when the curd was first stirred.

Coagulation temperatures above 80 deg. Fah. usually gave a firm curd of a high acidity and the curd showed a tendency to crumble during the cutting and cooking processes.

A curd of fairly good body and texture was secured in several batches of the cheese. One of the main dif-

ficulties of the curd which was soft at the time of cutting and when it had been firmed sufficiently to permit the mixing of the cream, the smaller particles were tough and corky in texture and would absorb only a very small amount of cream. A dry cheese with a very low yield was the result. The difference in the size of the curd particles was also very noticeable.

It was found that when the curd was not pressed but was drained in the vat with frequent stirring, there was a tendency for whey to separate from the cheese after it had been creamed.

The percentage yield of curd was quite variable depending upon the losses due to shattering and also to the moisture content.

The usual yield of curd was between 12 and 17 per cent. The percentage of times that crumbly and soft curd was obtained was so large that it is impossible to outline a plan of procedure that would result in a uniform quality of cheese made by the use of starter alone.

Results of experiments with the use of rennet with starter to coagulate the milk proved that a much firmer curd could be obtained. Unless a small amount of rennet was used the curd was tough and would not expel the whey

easily. The most desirable type of curd was obtained with the use of one cc. of rennet per 1000 pounds of milk with an acidity under .70 per cent. This curd had the desirable firmness at the time of cutting and the acidity was great enough to give a clean mild acid flavor. The use of larger amounts of rennet up to 15 cc. per 1000 pounds of milk resulted in a curd that was tough and rubbery even when the acidity was kept below .50 per cent.

When over 10 cc. of rennet per 1000 pounds of milk were used the curd had a tendency to cheddar or mat together throughout the cooking and the pressing periods.

Data from tables number five and seven show that when starter and rennet were used together to coagulate milk for cottage cheese the development of acid greatly affects the firmness of the curd, a firmer curd being produced with the higher acidities. The reason for this is undoubtedly due to the fact that rennet is activated greatly, within organic limits, by an increase in acidity.

The results that were obtained with the use of the curd knife, while they did not indicate the best method of handling the curd, showed considerable differences in the firmness of the curds and through experience this could be used as an indication of the condition of the curd for cutting.

SUMMARY

As the result of a study of several methods and variations of these methods of manufacture of cottage cheese the following facts have been obtained:

(1) Uniform quality cannot as a rule be obtained in cottage cheese when starter is used alone for coagulation. This is true when factors such as temperature, acidity, and method of firming the curd are kept uniform.

(2) Curd formed by the use of starter alone is too soft to permit cutting and stirring without breaking up of the curd.

(3) Coagulation temperatures under 70 deg. Fah. always resulted in exceptionally soft curds while coagulation temperatures above 80 deg. Fah. at times resulted in a soft curd and sometimes in a firm curd that crumbled easily.

(4) The results obtained indicated that a coagulation temperature between 70 deg. Fah. and 80 deg. Fah. gave the best type of curd.

(5) It was found that when the coagulation period exceeded 16 hours in length, the addition of one to two per cent of starter resulted in the production of sufficient acidity to give good coagulation.

(6) An excess of small curd particles resulted in a poor quality cheese because the smaller particles were tough in texture and absorbed less cream. The appearance of the cheese was not so desirable.

(7) Curd that is drained but not pressed will usually result in a leaky bodied cheese.

(8) Curd made with the use of starter alone required a longer period of time for absorbing the cream and less cream was taken up.

(9) Washing the curd in water at a temperature of 50 deg. Fah. firmed the curd considerably. Curd high in acid turned crumbly during the washing.

(10) Curd formed with the use of rennet was firmer in texture than when it was not used.

(11) The use of over one cc. of rennet per 1000 pounds of milk resulted in a tough curd that showed a decided tendency to mat together.

(12) When rennet was used the acidity developed exerted considerable influence on the firmness of the curd.

(13) It was found that one cc. of rennet per 1000 pounds of milk was sufficient to use if the acidity was allowed to develop to at least .70 per cent.

(14) Whey was expelled more rapidly from curd made with rennet and a lower final temperature of cooking was

used than when no rennet was used.

(15) If the curd was cut into cubes of three-eighths inch dimensions, the cooked particles were too small and too firm.

(16) When the curd was cut into cubes of three-fourths inch dimensions it resulted in a final product that was quite uniform but the cubes were too large to give an attractive appearance. Knives cutting the curd into cubes of one-half or five-eighths inch dimensions are recommended.

(17) Pressing the curd for 15 minutes expelled practically as much whey as when a one hour period was used.

(18) Curd made with the use of rennet absorbed cream more quickly than that made without rennet.

(19) Tests with curd knives showed considerable variation between rennet and starter formed curds. The variation between curds made with different amounts of rennet was considerable.

(20) There were small variations in the firmness of well coagulated curds obtained when starter was used alone.

(21) Soaking the curd in skim milk and then stirring in enough cream of high butterfat content to stand-

ardize the cheese to seven per cent fat gave a richer appearing product than when cream of low fat content was used.

(22) Homogenization of the cream used or the addition of a small amount of gelatin to the cream results in a richer appearing product than did cheese that was creamed with unprocessed cream.

(23) The use of small amounts of rennet in making cottage cheese gives a cheese that is more uniform and attractive in appearance. The texture of the curd is as satisfactory or more so than that obtained when acid is used alone as a coagulator. The curd is much easier to cook and less loss occurs from shattering. With uniformity and texture as the basis of a market standard, the use of rennet is essential in cottage cheese making.

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